

World Journal of *Orthopedics*

World J Orthop 2018 December 18; 9(12): 285-303





ORIGINAL ARTICLE

Retrospective Study

- 285 Socio-demographic factors impact time to discharge following total knee arthroplasty
Ihekweazu UN, Sohn GH, Laughlin MS, Goytia RN, Mathews V, Stocks GW, Patel AR, Brinker MR

Observational Study

- 292 Humeral retroversion and shoulder muscle changes in infants with internal rotation contractures following brachial plexus birth palsy
van de Bunt F, Pearl ML, van Essen T, van der Sluijs JA

CASE REPORT

- 300 Metallosis following a clip breakage in a total knee arthroplasty implant: A case report
Saad AI, Shahban SA, Fernandes R

ABOUT COVER

Editorial Board Member of *World Journal of Orthopedics*, Jian-Min Li, MD, Doctor, Professor, Surgeon, Department of Orthopedics, Qilu Hospital, Shandong University, Jinan 250012, Shandong Province, China

AIM AND SCOPE

World Journal of Orthopedics (*World J Orthop*, *WJO*, online ISSN 2218-5836, DOI: 10.5312) is a peer-reviewed open access academic journal that aims to guide clinical practice and improve diagnostic and therapeutic skills of clinicians.

WJO covers topics concerning arthroscopy, evidence-based medicine, epidemiology, nursing, sports medicine, therapy of bone and spinal diseases, bone trauma, osteoarthropathy, bone tumors and osteoporosis, minimally invasive therapy, diagnostic imaging. Priority publication will be given to articles concerning diagnosis and treatment of orthopedic diseases. The following aspects are covered: Clinical diagnosis, laboratory diagnosis, differential diagnosis, imaging tests, pathological diagnosis, molecular biological diagnosis, immunological diagnosis, genetic diagnosis, functional diagnostics, and physical diagnosis; and comprehensive therapy, drug therapy, surgical therapy, interventional treatment, minimally invasive therapy, and robot-assisted therapy.

We encourage authors to submit their manuscripts to *WJO*. We will give priority to manuscripts that are supported by major national and international foundations and those that are of great basic and clinical significance.

INDEXING/ABSTRACTING

World Journal of Orthopedics is now abstracted and indexed in PubMed, PubMed Central, Emerging Sources Citation Index (Web of Science), China National Knowledge Infrastructure (CNKI), and Superstar Journals Database.

EDITORS FOR THIS ISSUE

Responsible Assistant Editor: *Xiang Li*
Responsible Electronic Editor: *Ying-Na Bian*
Proofing Editor-in-Chief: *Lian-Sheng Ma*

Responsible Science Editor: *Ying Dou*
Proofing Editorial Office Director: *Jin-Lei Wang*

NAME OF JOURNAL
World Journal of Orthopedics

ISSN
 ISSN 2218-5836 (online)

LAUNCH DATE
 November 18, 2010

FREQUENCY
 Monthly

EDITOR-IN-CHIEF
Bao-Gan Peng, MD, PhD, Professor, Department of Spinal Surgery, General Hospital of Armed Police Force, Beijing 100039, China

EDITORIAL BOARD MEMBERS
 All editorial board members resources online at <http://www.wjgnet.com/2218-5836/editorialboard.htm>

EDITORIAL OFFICE
 Jin-Lei Wang, Director

World Journal of Orthopedics
 Baishideng Publishing Group Inc
 7901 Stoneridge Drive, Suite 501, Pleasanton, CA 94588, USA
 Telephone: +1-925-2238242
 Fax: +1-925-2238243
 E-mail: editorialoffice@wjgnet.com
 Help Desk: <http://www.f0publishing.com/helpdesk>
<http://www.wjgnet.com>

PUBLISHER
 Baishideng Publishing Group Inc
 7901 Stoneridge Drive,
 Suite 501, Pleasanton, CA 94588, USA
 Telephone: +1-925-2238242
 Fax: +1-925-2238243
 E-mail: bpgoffice@wjgnet.com
 Help Desk: <http://www.f0publishing.com/helpdesk>
<http://www.wjgnet.com>

PUBLICATION DATE
 December 18, 2018

COPYRIGHT
 © 2018 Baishideng Publishing Group Inc. Articles published by this Open-Access journal are distributed under the terms of the Creative Commons Attribution Non-commercial License, which permits use, distribution, and reproduction in any medium, provided the original work is properly cited, the use is non commercial and is otherwise in compliance with the license.

SPECIAL STATEMENT
 All articles published in journals owned by the Baishideng Publishing Group (BPG) represent the views and opinions of their authors, and not the views, opinions or policies of the BPG, except where otherwise explicitly indicated.

INSTRUCTIONS TO AUTHORS
<http://www.wjgnet.com/bpg/gerinfo/204>

ONLINE SUBMISSION
<http://www.f0publishing.com>

Retrospective Study

Socio-demographic factors impact time to discharge following total knee arthroplasty

Ugonna N Ihekweazu, Garrett H Sohn, Mitzi S Laughlin, Robin N Goytia, Vasilios Mathews, Gregory W Stocks, Anay R Patel, Mark R Brinker

Ugonna N Ihekweazu, Robin N Goytia, Vasilios Mathews, Gregory W Stocks, Anay R Patel, Mark R Brinker, Fondren Orthopedic Group, Houston, TX 77030, United States

Ugonna N Ihekweazu, Mitzi S Laughlin, Robin N Goytia, Vasilios Mathews, Gregory W Stocks, Anay R Patel, Mark R Brinker, Fondren Orthopedic Research Institute, Fondren Orthopedic Group, Houston, TX 77030, United States

Garrett H Sohn, Department of Orthopedic Surgery, Baylor College of Medicine, Houston, TX 77030, United States

ORCID number: Ugonna N Ihekweazu (0000-0002-6884-2197); Garrett H Sohn (0000-0002-3202-9671); Mitzi S Laughlin (0000-0002-6963-7144); Robin N Goytia (0000-0002-9781-7628); Vasilios Mathews (0000-0002-1862-4124); Gregory W Stocks (0000-0002-2943-5548); Anay R Patel (0000-0001-9183-4905); Mark R Brinker (0000-0001-7140-1635).

Author contributions: Ihekweazu UN, Goytia RN, Mathews V, Stocks GW, Patel AR and Brinker MR contributed to the study conception and design; Ihekweazu UN, Goytia RN, Mathews V, Stocks GW and Patel AR contributed to the data acquisition and data interpretation; Laughlin MS contributed the data analysis, data interpretation and preparation of the tables and figures; Ihekweazu UN, Sohn GH and Laughlin MS contributed to the literature review and the writing of the article; all authors have approved this manuscript prior to submission and believe that this manuscript represents honest work.

Institutional review board statement: This study was evaluated and an IRB exemption was given for this work by the Texas Orthopedic Hospital's IRB (TOH203e).

Informed consent statement: Patients were not required to give informed consent to the study because the analysis used anonymous clinical data and the study was given an IRB exemption.

Conflict-of-interest statement: All authors declare no conflicts-of-interest related to this article but the following authors have financial relationships to report in general: Robin Goytia reports personal fees from Innomed, outside the submitted work;

Gregory Stocks reports stock ownership from Nimbic Systems, Inc., outside the submitted work; Mark Brinker reports personal fees from Zimmer Biomet, outside the submitted work.

Open-Access: This article is an open-access article which was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>

Manuscript source: Unsolicited manuscript

Corresponding author to: Mitzi S Laughlin, PhD, Senior Researcher, Chief Scientist, Fondren Orthopedic Research Institute, Fondren Orthopedic Group, 7401 S. Main, Houston, TX 77030, United States. mitzi.laughlin@fondren.com
Telephone: +1-713-7943408

Received: October 4, 2018

Peer-review started: October 4, 2018

First decision: October 29, 2018

Revised: November 6, 2018

Accepted: December 10, 2018

Article in press: December 10, 2018

Published online: December 18, 2018

Abstract

AIM

To determine social, logistical and demographic factors that influence time to discharge in a short stay pathway (SSP) by following total knee arthroplasty (TKA).

METHODS

The study included primary TKA's performed in a high-volume arthroplasty center from January 2016 through

December 2016. Potential variables associated with increased hospital length of stay (LOS) were obtained from patient medical records. These included age, gender, race, zip code, body mass index (BMI), number of pre-operative medications used, number of narcotic medications used, number of patient reported allergies (PRA), simultaneous bilateral surgery, tobacco use, marital status, living arrangements, distance traveled for surgery, employment history, surgical day of the week, procedure end time and whether the surgery was performed during a major holiday week. Multivariate step-wise regression determined the impact of social, logistical and demographic factors on LOS.

RESULTS

Eight hundred and six consecutive primary SSP TKA's were included in this study. Patients were discharged at a median of 49 h (post-operative day two). The following factors increased LOS: Simultaneous bilateral TKA [46.1 h longer ($P < 0.001$)], female gender [4.3 h longer ($P = 0.012$)], age [3.5 h longer per ten-year increase in age ($P < 0.001$)], patient-reported allergies [1.1 h longer per allergy reported ($P = 0.005$)], later procedure end-times [0.8 h longer per hour increase in end-time ($P = 0.004$)] and Black or African American patients [6.1 h longer ($P = 0.047$)]. Decreased LOS was found in married patients [4.8 h shorter ($P = 0.011$)] and TKA's performed during holiday weeks [9.4 h shorter ($P = 0.011$)]. Non-significant factors included: BMI, median income, patient's living arrangement, smoking status, number of medications taken, use of pre-operative pain medications, distance traveled to hospital, and the day of surgery.

CONCLUSION

The cost of TKA is dependent upon LOS, which is affected by multiple factors. The clinical care team should acknowledge socio-demographic factors to optimize LOS.

Key words: Total knee replacement; Total knee arthroplasty; Cost; Risk factors; Length of stay

© **The Author(s) 2018.** Published by Baishideng Publishing Group Inc. All rights reserved.

Core tip: In an effort to decrease post-operative length of stay (LOS), many institutions continue to develop optimal discharge pathways. Since LOS is dependent upon many variables, we sought to define which socio-demographic factors influence LOS in total knee arthroplasty (TKA). Six factors were found to increase LOS: Age, gender, Black or African American race, simultaneous bilateral TKA, later procedure end times and number of PRA. Two factors decreased LOS, patient being married and surgery during a major public holiday week. While none of the patient specific factors are modifiable by the clinician, we do have the ability to optimize surgical schedule and allocation of resources.

Ihekweazu UN, Sohn GH, Laughlin MS, Goytia RN, Mathews V, Stocks GW, Patel AR, Brinker MR. Socio-demographic factors impact time to discharge following total knee arthroplasty. *World J Orthop* 2018; 9(12): 285-291

URL: <https://www.wjgnet.com/2218-5836/full/v9/i12/285.htm>

DOI: <https://dx.doi.org/10.5312/wjo.v9.i12.285>

INTRODUCTION

Increased utilization of total joint arthroplasty (TJA) is expected to result in a pronounced economic burden on the United States health care system^[1]. Subsequently, cost reductions even at the individual case level can translate into a substantial cost savings to the overall system^[2]. In-hospital length of stay (LOS) has been shown to directly influence the total cost of joint arthroplasty when patients are discharged home^[3,4]. Since LOS is a modifiable cost factor, increased focus has been placed on implementing measures that aim to discharge patients from the hospital as soon as safely possible. The recent development of short stay pathways is a direct result of advancements in surgical, anesthetic and rehabilitation techniques. While there are concerns regarding the overall safety of short stay pathways (SSP) compared to conventional postoperative pathway (CPP), the literature suggests that drastic reductions in LOS can be accomplished without increasing complication rates^[5].

Factors influencing LOS such as age, gender and perioperative complications have been previously described in the literature under CPP for hip and knee arthroplasty^[6,7]. At the earliest, patients in these CPP studies were discharged on the 3rd day following surgery^[6-8]. Keswani *et al*^[8] found that patients with later surgical start times and end of the week procedure days (Thursday and Friday) had longer LOS in a CPP. However, a separate study performed at an institution utilizing a SSP found that surgical day of the week had no correlation with LOS^[9]. Another institution utilizing SSP investigated the influence of preoperative patient characteristics and perioperative surgical factors related to prolonged LOS^[10,11]. Regardless there remains limited data on the factors influencing LOS following TKA in a SSP.

The primary purpose of this study was to assess the influence of social, logistical and demographic factors on time to discharge in a SSP for TKA. The findings from this study may further enhance preoperative and perioperative risk stratification models that already incorporate patient characteristics and perioperative surgical factors but neglect other potentially influential variables.

MATERIALS AND METHODS

Methods

A retrospective chart review was performed for a consecutive series of 806 elective primary TKA's performed at a single specialty hospital from January

2016 to December 2016. All procedures were performed by one of 3 experienced surgeons, each performing more than 250 TKAs per year. All surgeries, regardless of LOS, were performed using the hospital's SSP for each phase of care. This study was evaluated and an Institutional Review Board (IRB) exemption was given for this work by the Texas Orthopedic Hospital IRB (TOH203e).

Short stay protocol

All patients at this institution undergo a formal pre-operative screening process to ensure they are safe for surgery and postoperative care within our specialty hospital. Active renal replacement therapy, active lung disease requiring home oxygen support, or active cardiac disease requiring a defibrillator exclude the patient from surgery at this institution. Each patient is medicated preoperatively with celecoxib 200 mg, Neurontin 100 mg, and acetaminophen 650 mg. Intra-operative anesthesia consists of a propofol infusion with no inhalation anesthetic and no muscle relaxation. During the procedure a periarticular anesthetic of weight-based ropivacaine 0.5% and morphine 5-10 mg is injected into the soft tissues prior to closure. All patients are given 1 g intravenous (IV) tranexamic acid prior to incision and 1 gram prior to closure, unless it is contraindicated, at which point it is administered topically. Post-operative medication regimen consists of a combination of hydrocodone, tramadol, methocarbamol, dexamethasone and IV ketorolac. Deep vein thrombosis prophylaxis consists of aspirin or rivaroxaban per surgeon discretion and is continued for 4 wk. Patients are mobilized approximately 2 h after surgery with physical therapists. Standing is attempted, and if tolerated, patients are allowed to walk with a walker and assistance as far as they can tolerate. Continuous passive motion devices were used during the study period per surgeon discretion. The following morning patients undergo their second session with the physical therapists. The three surgeons included in this study independently round on their patients on all days, including weekends and holidays. Patients were discharged as soon as they had adequate oral pain control, are safe to ambulate and mobilize with an assistive device and are hemodynamically stable.

Study outcomes

Potential variables associated with increased hospital LOS were obtained from patient medical records. These included age, gender, race, zip code, body mass index (BMI), number of pre-operative medications used, number of narcotic medications used, number of patient reported allergies (PRA), simultaneous bilateral surgery, tobacco use, marital status, living arrangements, distance traveled for surgery, employment history, surgical day of the week, procedure end time and whether the surgery was performed during a major holiday week. Thanksgiving, Christmas and New Year's Eve were the major holidays included in the study. The patient's zip

code was used to obtain the median household income of the zip code from the 2016 American Community Survey performed by the United States Census Bureau^[12].

Baseline demographics, surgical factors, and social factors were summarized by mean (\pm SD) for continuous factors or by count and percentages for categorical factors in order to characterize the study population. Multivariate regression analysis was performed to determine the contribution of demographic, logistical and social factors on LOS. A stepwise model was used to determine the number of factors significantly associated with LOS. Statistical significance was defined as $P < 0.05$ and SPSS 24 (IBM Corp., Armonk, NY, United States) was used for statistical analyses.

RESULTS

A total of 806 primary TKA cases were included in the study. There were 491 female (60.9%) patients and the average age of the study population was 64.5 years. 76.6% of the study population were identified as White, 11.4% as other, 7.8% black/African American, 2.2% identified as Asian and 1.9% declined to state. The median LOS was 49.0 h with a range from 18-236 h. All subject characteristics that were included in the analysis are depicted in Table 1.

In our study population, the constant (or baseline regression model) for LOS was 22.7 h ($P = 0.004$). Adding or subtracting beta coefficients for other factors predicts individual patient LOS. Multiple regression identified six factors that increased LOS (Table 2): Simultaneous bilateral TKA [46.1 h longer ($P < 0.001$)], female gender [4.3 h longer ($P = 0.012$)], age [3.5 h longer per ten-year increase in age ($P < 0.001$)], number of PRA's [1.1 h longer per each reported number of allergies ($P = 0.005$)], later procedure end-times [0.8 h longer per hour increase in end-time ($P = 0.040$)] and Black or African American patients [6.1 h longer ($P = 0.047$)]. Two factors were found to decrease LOS: Patients being married [4.8 h shorter ($P = 0.011$)] and TKAs performed during major holiday weeks [9.4 h shorter ($P = 0.011$)]. Non-significant factors included: BMI, median income, patient's living arrangement, smoking status, number of medications taken, use of pre-operative pain medications, distance traveled to hospital, and the day of surgery.

DISCUSSION

LOS is a modifiable cost factor in the overall expense of TJA. Increased emphasis has been placed on both employing SSP and optimizing risk stratification models that identify those who may or may not be appropriate candidates for SSP. Our study identified simultaneous bilateral TKA, female gender, increased age, increased number of PRA, later surgery end time and race identified as Black or African American as factors that increased LOS. Two factors, patient being married and procedures

Table 1 Baseline subject characteristics

Factor	mean \pm SD or <i>n</i> (%)
Number of patients	806
Gender	
Male	315 (39.1)
Female	491 (60.9)
Age (yr)	64.5 \pm 8.5
Race	
Asian	18 (2.2)
Black/African American	63 (7.8)
White	617 (76.6)
Other	94 (11.4)
Decline to state	16 (1.9)
Body mass index	33.81 \pm 7.4
Employed	347 (43.1)
Median income by zip code	\$66586 \pm 25562
Marital Status	
Single	105 (13.0)
Married	593 (73.6)
Widow/widower	66 (8.2)
Divorced	42 (5.2)
Patient lives alone (Y)	99 (12.3)
Smoker	
Current	68 (8.4)
Former	232 (28.8)
Never	506 (62.8)
Number of allergies	1.5 \pm 2.2
Number of medications	6.1 \pm 4.8
Pre-operative pain meds (Y)	108 (13.4)
Simultaneous bilateral total knee arthroplasty	37 (4.6)
Distance from hospital (miles)	61.95 \pm 122.8
Day of surgery	
Monday	242 (30.0)
Tuesday	175 (21.7)
Wednesday	129 (16.0)
Thursday	194 (24.1)
Friday	61 (7.6)
Saturday	5 (0.6)
Holiday week surgery	43 (5.3)
Surgery end time (h:min)	11:05 \pm 2:22

performed during major holiday weeks decreased LOS.

Increased age and female gender are factors that are known to correlate with increased LOS in SSP^[11,13]. Both simultaneous bilateral TKA^[14] and patient identified race as non-Caucasian^[15] have been shown to increase LOS in CPP as well as SSP. Our data showed that patients identifying as Black or African American had a significantly longer LOS after TKA, while other racial groups (White and Other) showed no difference in LOS. Racial disparities in utilization, complication rates and outcomes of arthroplasty are prevalent in the literature^[15-17], however, race is often confounded with socioeconomic factors. In our study, Black patients had a longer LOS but median household income was not a significant factor influencing LOS. Further analysis showed that the median income of Black patients in our study was just over \$41000 while both White and Other patients was over \$60000 (Figure 1). According to the American Community Survey the median income for the United States in 2016 was \$55322^[12], so in our patient population Black patients were well under the United States median income while White and Other

patients were slightly above. Thus, increased LOS in Black patients may not be entirely due to race, as socioeconomic factors may also be confounded by race. Future studies will need to further define the complex relationships between race, socioeconomic status, perioperative outcomes and LOS in TJA.

To our knowledge, marital status has not previously been shown to demonstrate any influence on LOS following TKA. While limited, the literature outside of orthopedics suggests that being married may be associated with better treatment outcomes^[18,19]. However, marital status has been shown to affect outcomes following TKA as patients that are married have better overall outcomes following TKA^[20]. In our study, married patients had a decreased postoperative LOS. Our findings corroborate the general trend in the literature, with a positive association between being married and improved treatment outcomes. Notably, marital status has recently been identified as a key variable that should be investigated in future research on outcomes of knee and hip surgery^[21].

Prior studies indicate that increasing amounts of PRA's is associated with worse outcomes following total hip and knee arthroplasty^[22-24]. Interestingly, the patient reported "allergy" is often a misnomer as only 15% of PRA's studied in a community hospital setting represented a true IgE mediate hypersensitivity reaction^[25]. In a study utilizing data from the Canadian Community Health registry, an association between mood and anxiety disorders and PRA reporting was demonstrated^[26]. As the relationship between PRA and psychiatric disorders is further elucidated, their impact on all aspects of TJA is becoming more apparent. In a prospective study of 446 patients undergoing primary hip and knee arthroplasty, Otero *et al*^[22] found that patients reporting at least 1 allergy had significantly lower postoperative SF-36 physical component score compared to those reporting no allergies. In a retrospective review, McLawhorn *et al*^[23] demonstrated that increasing number of PRA's was associated with both worse satisfaction and Western Ontario and McMaster Universities Arthritis Index scores, in addition to increased LOS following TKA in a CPP. The median LOS of the patients included in their TKA cohort was 4.0 d. Our study found that for each reported allergy, LOS increased by 0.8 h. While this may seem to be an insignificant amount of time, it is not uncommon to encounter patients with many PRA's in practice; in our study, one patient reported twenty-three. In an SSP, increasing the LOS by just a few hours may represent the difference in an additional day spent in the hospital.

The relationship between surgical day of the week and LOS has previously been studied in both CPP and SSP. In separate retrospective reviews, both Muppavarapu *et al*^[27] and Keswani *et al*^[8] found that patients who underwent TJA or total hip arthroplasty (THA) respectively, on Thursday or Friday had significantly longer hospital LOS compared to patients undergoing those procedures earlier in the week. These two studies represented a CPP as the LOS of the patients included these studies was

Table 2 Significant factors predicting length of stay

Factor	Beta coefficient (h) ¹	Std. error	P value
Constant	22.7	7.8	0.004
Simultaneous bilateral total knee arthroplasty	46.1	4.1	< 0.001
Gender (female)	4.3	1.7	0.012
Age (per 10 yr)	3.5	1.0	< 0.001
Patient is married	-4.8	1.9	0.011
Number of allergies	1.1	0.4	0.005
Holiday week surgery	-9.4	3.6	0.011
Surgery end time	0.8	0.4	0.040
Black/African American	6.1	3.0	0.047

¹In our study population, the constant for length of stay (LOS) was 22.7 h. Adding or subtracting beta coefficients for other factors predicts individual patient LOS.

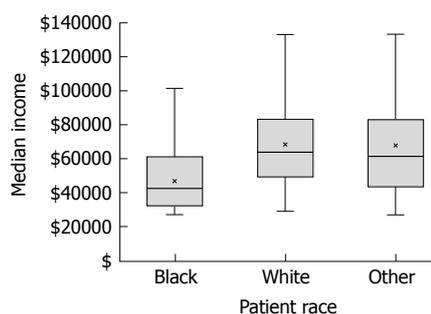


Figure 1 Median income level by race with the bold horizontal line representing the median, the box shows the 25% to 75% range, the x is the mean and the whiskers represent the entire range of the data.

greater than 3 d. A comprehensive PubMed search found only one study that investigates the effect of surgical day of the week on LOS in an SSP for total joint arthroplasty. In a cohort of patients with an average LOS of < 2 d, Edwards *et al*^[9] found that surgical day of the week did not influence time to discharge. Our results were similar as surgical day of the week did not influence LOS in our SSP. These findings suggest that as LOS decreases the overall impact of performing a procedure towards the end of the week may diminish.

The influence of surgical start time on LOS has been investigated across several surgical subspecialties with the evidence suggesting that as cases begin later in the day, LOS increases^[28,29]. Earnest *et al*^[28] suspected that initial post-operative care is delayed for patients admitted in the afternoon because clinical workup and management usually occurs in the morning. Only one study has investigated the influence of surgical timing on LOS in total joint arthroplasty. In a cohort of THA patients receiving conventional postoperative care pathways, Keswani *et al*^[8] found that procedures starting after 2 PM were associated with longer LOS compared to procedures starting prior to 2 PM. We found that LOS was slightly shorter for every hour later the procedure ended. In our institution's SSP, post-operative protocols do not depend on the time of day as staffing is consistent between shifts. Patients are encouraged to work with a physical therapist just a few hours after surgery when clinically feasible. Our findings suggest that unlike CPP, in SSP the

surgical start time of the procedure is less critical.

The relationship between public holidays and LOS across all medical fields has never been reported, a few studies have sought to understand the influence of holidays on clinical outcomes and readmission^[30-32]. In our study, patients undergoing TKA during major public holiday weeks were found to have decreased LOS as compared to patients having surgery during a normal week. Several factors likely influence these findings including patient, surgeon and staff related variables. As our study included three surgeons, the most senior surgeon performed fewer procedures during holiday weeks and also had a slightly higher LOS average, possibly confounding the lower LOS holiday week results. While these results do leave room for speculation, the present study could not delineate any additional conclusions from these findings; therefore this is an area that future studies should consider investigating further.

Our study had several limitations. First, the data used was retrospectively collected and therefore susceptible to inherent bias in its analysis. Secondly, race identification was limited to what was reported in the chart and the 'other' classification likely encompassed a variety of distinct ethnicities that could not be further discerned. Third, there was potential for type II statistical error as certain variables approached but did not reach significance in this study. As it pertains to LOS, several variables that were originally thought to be relevant factors were not. In particular, distance traveled and pre-operative narcotic use did not reach significance in our cohort.

In an effort to decrease post-operative LOS, many institutions continue to develop optimal discharge pathways following TKA. Since LOS is dependent upon many variables, we sought to define which social, logistical and demographic factors influence LOS in TKA. Six factors were found to increase LOS in a SSP: Age, gender, Black or African American race, simultaneous bilateral TKA, later procedure end times and number of PRA's. Two factors decreased LOS in an SSP, patient being married and surgery during a major public holiday week. While none of the patient specific factors (*e.g.*, age, race, gender, marital status, socioeconomic status,

and PRA's) are modifiable by the clinician, we do have the ability to optimize surgical schedule and allocation of resources. When refining predictive models for LOS, in addition to considering known clinical factors, the care team should also appreciate the extent that social, demographic and logistical factors influence LOS. Furthermore, the influence of these factors may depend on whether a CPP or an SSP model is being employed.

ARTICLE HIGHLIGHTS

Research background

Time to discharge or in-hospital length of stay (LOS) has been shown to directly influence the total cost of joint arthroplasty when patients are discharged home. Since LOS is a modifiable cost factor, increased focus has been placed on implementing measures that aim to discharge patients from the hospital as soon as safely possible. The recent development of short stay pathways is a direct result of advancements in surgical, anesthetic and rehabilitation techniques. Traditional factors such as age, gender, comorbidities and perioperative complications have been studied extensively and influence LOS. Patient social, logistical and demographic factors are non-modifiable factors but potentially influence LOS.

Research motivation

The motivation behind this research was to further improve short stay pathways by evaluating non-traditional factors that potentially could influence LOS. Our hypothesis was that social, logistical and demographic factors influence LOS following total knee arthroplasty (TKA) in a short stay pathway.

Research objectives

The primary purpose of this study was to assess the influence of social, logistical and demographic factors on time to discharge in a short stay pathway following TKA. The findings from this study may further enhance preoperative and perioperative risk stratification models that already incorporate patient characteristics and perioperative surgical factors but neglect other potentially influential variables.

Research methods

A retrospective chart review was performed for a consecutive series of 806 elective primary TKA's performed at a single specialty hospital from January 2016 to December 2016. Potential variables associated with increased hospital LOS were obtained from patient medical records. These included age, gender, race, zip code, body mass index (BMI), number of pre-operative medications used, number of narcotic medications used, number of patient reported allergies (PRA), simultaneous bilateral surgery, tobacco use, marital status, living arrangements, distance traveled for surgery, employment history, surgical day of the week, procedure end time and whether the surgery was performed during a major holiday week. Thanksgiving, Christmas and New Year's Eve were the major holidays included in the study. Baseline demographics, surgical factors, and social factors were summarized by mean (\pm SD) for continuous factors or by count and percentages for categorical factors in order to characterize the study population. Multivariate regression analysis was performed to determine the contribution of demographic, logistical and social factors on LOS.

Research results

Patients were discharged at a median of 49 h (post-operative day two). Six factors increased LOS: Simultaneous bilateral TKA, female gender, age, patient-reported allergies, later procedure end-times, and Black or African American patients. Decreased LOS was found in married patients and TKA's performed during holiday weeks. Non-significant factors included: BMI, median income, patient's living arrangement, smoking status, number of medications taken, use of pre-operative pain medications, distance traveled to hospital, and the day of surgery.

Research conclusions

The cost of TKA is dependent upon LOS, which is affected by multiple factors.

The clinical care team should acknowledge socio-demographic factors to further optimize short stay pathways and decrease LOS.

Research perspectives

In an effort to decrease post-operative LOS, many institutions continue to develop optimal discharge pathways following TKA. Since LOS is dependent upon many variables, we sought to define which social, logistical and demographic factors influence LOS in TKA. Six factors were found to increase LOS in a short stay pathway: Age, gender, Black or African American race, simultaneous bilateral TKA, later procedure end times and number of PRA's. Two factors decreased LOS: Patient being married and surgery during a major public holiday week. While none of the patient specific factors (*e.g.*, age, race, gender, marital status, socioeconomic status, and PRA's) are modifiable by the clinician, we do have the ability to optimize surgical schedule and allocation of resources. When refining predictive models for LOS, in addition to considering known clinical factors, the care team should also appreciate the extent that social, demographic and logistical factors influence LOS.

REFERENCES

- 1 **Kurtz S**, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am* 2007; **89**: 780-785 [PMID: 17403800 DOI: 10.2106/JBJS.F.00222]
- 2 **Teeny SM**, York SC, Benson C, Perdue ST. Does shortened length of hospital stay affect total knee arthroplasty rehabilitation outcomes? *J Arthroplasty* 2005; **20**: 39-45 [PMID: 16214001 DOI: 10.1016/j.arth.2005.04.025]
- 3 **Cram P**, Lu X, Kates SL, Singh JA, Li Y, Wolf BR. Total knee arthroplasty volume, utilization, and outcomes among Medicare beneficiaries, 1991-2010. *JAMA* 2012; **308**: 1227-1236 [PMID: 23011713 DOI: 10.1001/2012.jama.11153]
- 4 **Meyers SJ**, Reuben JD, Cox DD, Watson M. Inpatient cost of primary total joint arthroplasty. *J Arthroplasty* 1996; **11**: 281-285 [PMID: 8713907 DOI: 10.1016/S0883-5403(96)80079-9]
- 5 **Stambough JB**, Nunley RM, Curry MC, Steger-May K, Clohisy JC. Rapid recovery protocols for primary total hip arthroplasty can safely reduce length of stay without increasing readmissions. *J Arthroplasty* 2015; **30**: 521-526 [PMID: 25683296 DOI: 10.1016/j.arth.2015.01.023]
- 6 **Rissanen P**, Aro S, Paavolainen P. Hospital- and patient-related characteristics determining length of hospital stay for hip and knee replacements. *Int J Technol Assess Health Care* 1996; **12**: 325-335 [PMID: 8707504 DOI: 10.1017/S0266462300009661]
- 7 **Forrest G**, Fuchs M, Gutierrez A, Girardy J. Factors affecting length of stay and need for rehabilitation after hip and knee arthroplasty. *J Arthroplasty* 1998; **13**: 186-190 [PMID: 9526212 DOI: 10.1016/S0883-5403(98)90097-3]
- 8 **Keswani A**, Beck C, Meier KM, Fields A, Bronson MJ, Moucha CS. Day of Surgery and Surgical Start Time Affect Hospital Length of Stay After Total Hip Arthroplasty. *J Arthroplasty* 2016; **31**: 2426-2431 [PMID: 27491449 DOI: 10.1016/j.arth.2016.04.013]
- 9 **Edwards PK**, Hadden KB, Connelly JO, Barnes CL. Effect of Total Joint Arthroplasty Surgical Day of the Week on Length of Stay and Readmissions: A Clinical Pathway Approach. *J Arthroplasty* 2016; **31**: 2726-2729 [PMID: 27378632 DOI: 10.1016/j.arth.2016.05.057]
- 10 **Sibia US**, King PJ, MacDonald JH. Who Is Not a Candidate for a 1-Day Hospital-Based Total Knee Arthroplasty? *J Arthroplasty* 2017; **32**: 16-19 [PMID: 27491443 DOI: 10.1016/j.arth.2016.06.055]
- 11 **Sibia US**, MacDonald JH, King PJ. Predictors of Hospital Length of Stay in an Enhanced Recovery After Surgery Program for Primary Total Hip Arthroplasty. *J Arthroplasty* 2016; **31**: 2119-2123 [PMID: 27067175 DOI: 10.1016/j.arth.2016.02.060]
- 12 **U.S. Census Bureau**. American Community Survey, 2016 [cited 20 April 2018]. Detailed tables [Internet]. Available from: URL: https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml
- 13 **Husted H**, Holm G, Jacobsen S. Predictors of length of stay and

- patient satisfaction after hip and knee replacement surgery: fast-track experience in 712 patients. *Acta Orthop* 2008; **79**: 168-173 [PMID: 18484241 DOI: 10.1080/17453670710014941]
- 14 **Suleiman LI**, Edelstein AI, Thompson RM, Alvi HM, Kwasny MJ, Manning DW. Perioperative Outcomes Following Unilateral Versus Bilateral Total Knee Arthroplasty. *J Arthroplasty* 2015; **30**: 1927-1930 [PMID: 26072300 DOI: 10.1016/j.arth.2015.05.039]
 - 15 **Inneh IA**. The Combined Influence of Sociodemographic, Preoperative Comorbid and Intraoperative Factors on Longer Length of Stay After Elective Primary Total Knee Arthroplasty. *J Arthroplasty* 2015; **30**: 1883-1886 [PMID: 26044998 DOI: 10.1016/j.arth.2015.05.032]
 - 16 **Martsof GR**, Barrett ML, Weiss AJ, Kandrack R, Washington R, Steiner CA, Mehrotra A, SooHoo NF, Coffey R. Impact of Race/Ethnicity and Socioeconomic Status on Risk-Adjusted Hospital Readmission Rates Following Hip and Knee Arthroplasty. *J Bone Joint Surg Am* 2016; **98**: 1385-1391 [PMID: 27535441 DOI: 10.2106/JBJS.15.00884]
 - 17 **Singh JA**, Lu X, Rosenthal GE, Ibrahim S, Cram P. Racial disparities in knee and hip total joint arthroplasty: an 18-year analysis of national Medicare data. *Ann Rheum Dis* 2014; **73**: 2107-2115 [PMID: 24047869 DOI: 10.1136/annrheumdis-2013-203494]
 - 18 **Franks MM**, Stephens MA, Rook KS, Franklin BA, Keteyian SJ, Artinian NT. Spouses' provision of health-related support and control to patients participating in cardiac rehabilitation. *J Fam Psychol* 2006; **20**: 311-318 [PMID: 16756407 DOI: 10.1037/0893-3200.20.2.311]
 - 19 **Aizer AA**, Chen MH, McCarthy EP, Mendu ML, Koo S, Wilhite TJ, Graham PL, Choueiri TK, Hoffman KE, Martin NE, Hu JC, Nguyen PL. Marital status and survival in patients with cancer. *J Clin Oncol* 2013; **31**: 3869-3876 [PMID: 24062405 DOI: 10.1200/JCO.2013.49.6489]
 - 20 **Roubion RC**, Fox RS, Townsend LA, Pollock GR, Leonardi C, Dasa V. Does Marital Status Impact Outcomes After Total Knee Arthroplasty? *J Arthroplasty* 2016; **31**: 2504-2507 [PMID: 27240961 DOI: 10.1016/j.arth.2016.04.017]
 - 21 **Lieberman JR**, Teuscher D, Berry DJ, Vail TP. AAOS' comments on CMS' Comprehensive Care for Joint Replacement Payment Model for Acute Care Hospitals Furnishing Lower Extremity Joint Replacement Services Proposed Rule [CMS-5516-P]. 2015. Available from: URL: <https://innovation.cms.gov/initiatives/cjr>
 - 22 **Otero JE**, Graves CM, Gao Y, Olson TS, Dickinson CC, Chalus RJ, Vittetoe DA, Goetz DD, Callaghan JJ. Patient-Reported Allergies Predict Worse Outcomes After Hip and Knee Arthroplasty: Results From a Prospective Cohort Study. *J Arthroplasty* 2016; **31**: 2746-2749 [PMID: 27600302 DOI: 10.1016/j.arth.2016.07.040]
 - 23 **McLawhorn AS**, Bjerke-Kroll BT, Blevins JL, Sculco PK, Lee YY, Jerabek SA. Patient-Reported Allergies Are Associated With Poorer Patient Satisfaction and Outcomes After Lower Extremity Arthroplasty: A Retrospective Cohort Study. *J Arthroplasty* 2015; **30**: 1132-1136 [PMID: 25702595 DOI: 10.1016/j.arth.2015.01.043]
 - 24 **Graves CM**, Otero JE, Gao Y, Goetz DD, Willenborg MD, Callaghan JJ. Patient reported allergies are a risk factor for poor outcomes in total hip and knee arthroplasty. *J Arthroplasty* 2014; **29**: 147-149 [PMID: 25034881 DOI: 10.1016/j.arth.2014.02.040]
 - 25 **Chen CJ**, Cheng CF, Lin HY, Hung SP, Chen WC, Lin MS. A comprehensive 4-year survey of adverse drug reactions using a network-based hospital system. *J Clin Pharm Ther* 2012; **37**: 647-651 [PMID: 22646235 DOI: 10.1111/j.1365-2710.2012.01359.x]
 - 26 **Patten SB**, Williams JV. Self-reported allergies and their relationship to several Axis I disorders in a community sample. *Int J Psychiatry Med* 2007; **37**: 11-22 [PMID: 17645194 DOI: 10.2190/L811-0738-10NG-7157]
 - 27 **Muppavarapu RC**, Chaurasia AR, Schwarzkopf R, Matzkin EG, Cassidy CC, Smith EL. Total joint arthroplasty surgery: does day of surgery matter? *J Arthroplasty* 2014; **29**: 1943-1945 [PMID: 25015754 DOI: 10.1016/j.arth.2014.06.004]
 - 28 **Earnest A**, Chen MI, Seow E. Exploring if day and time of admission is associated with average length of stay among inpatients from a tertiary hospital in Singapore: an analytic study based on routine admission data. *BMC Health Serv Res* 2006; **6**: 6 [PMID: 16426459 DOI: 10.1186/1472-6963-6-6]
 - 29 **Slaughter KN**, Frumovitz M, Schmelzer KM, Nick AM, Fleming ND, dos Reis R, Munsell MF, Westin SN, Soliman PT, Ramirez PT. Minimally invasive surgery for endometrial cancer: does operative start time impact surgical and oncologic outcomes? *Gynecol Oncol* 2014; **134**: 248-252 [PMID: 24945591 DOI: 10.1016/j.ygyno.2014.06.007]
 - 30 **Sebghatollahi V**, Ghomi K, Tamizifar B, Minakari M, Khodadoustan M. The Relationship between the Time of Endoscopy and Morbidity and Mortality Rates in Patients with Upper Gastrointestinal Bleeding. *Adv Biomed Res* 2017; **6**: 81 [PMID: 28808647]
 - 31 **Orsini J**, Rajayer S, Ahmad N, Din N, Morante J, Malik R, Shim A. Effects of time and day of admission on the outcome of critically ill patients admitted to ICU. *J Community Hosp Intern Med Perspect* 2016; **6**: 33478 [PMID: 27987290 DOI: 10.3402/jchimp.v6.33478]
 - 32 **Richards MK**, Yanez D, Goldin AB, Grieb T, Murphy WM, Drugas GT. Factors associated with 30-day unplanned pediatric surgical readmission. *Am J Surg* 2016; **212**: 426-432 [PMID: 26924805 DOI: 10.1016/j.amjsurg.2015.12.012]

P- Reviewer: Fenichel I, Wu CC **S- Editor:** Ji FF **L- Editor:** A
E- Editor: Bian YN



Observational Study

Humeral retroversion and shoulder muscle changes in infants with internal rotation contractures following brachial plexus birth palsy

Fabian van de Bunt, Michael L Pearl, Tom van Essen, Johannes A van der Sluijs

Fabian van de Bunt, Tom van Essen, Johannes A van der Sluijs, Department of Orthopedics, Amsterdam UMC, VU University Medical Center, Amsterdam 1081 HV, Netherlands

Michael L Pearl, Department of Shoulder and Elbow Surgery, Kaiser Permanente Medical Center, Los Angeles, Ca 90027, United States

ORCID number: Fabian van de Bunt (0000-0002-4169-0322); Michael L Pearl (0000-0003-3407-481X); Tom van Essen (0000-0001-9256-9269); Johannes A van der Sluijs (0000-0002-9879-8908).

Authorship: All authors made significant contributions to the manuscript, conforming to the standard proposed by the ICMJE.

Author contributions: van de Bunt F designed the study, and performed data collection, analysis and interpretation of data, writing of (the first draft) of the manuscript, critical evaluation of the intelligent content of the final version; Pearl ML designed the study and performed data interpretation, writing of the manuscript, critical evaluation of the intelligent content of the final version; van Essen T performed data collection, analysis and interpretation of data, writing of (the first draft) manuscript; van der Sluijs JA designed the study and performed data interpretation, writing of the manuscript, and critical evaluation of the intelligent content of the final version.

Institutional review board statement: We are pleased to confirm that the Medical Research Involving Human Subjects Act (WMO) does not apply to the above-mentioned study and that an official approval of this study by our committee is not required.

Informed consent statement: We received an IRB waiver from the Institutional review board since this was a retrospective observational study, utilizing MRI scans made strictly for clinical purposes. MRIs were all anonymized by the Radiology department before conducting our study. See the attached IRB statement.

Conflict-of-interest statement: The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants;

participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

STROBE statement: The authors have read the STROBE Statement-checklist of items, and the manuscript was prepared and revised according to the STROBE Statement-checklist of items.

Open-Access: This article is an open-access article which was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>

Manuscript source: Unsolicited manuscript

Corresponding author to: Fabian van de Bunt, MD, MSc, Doctor, MD, Department of Orthopedics, Amsterdam UMC, VU University Medical Center, De Boelelaan 1117, Amsterdam 1081 HV, Netherlands. fabianvdbunt@gmail.com
Telephone: +31-64-8482593

Received: August 22, 2018
Peer-review started: August 22, 2018
First decision: October 4, 2018
Revised: October 16, 2018
Accepted: November 15, 2018
Article in press: November 15, 2018
Published online: December 18, 2018

Abstract

AIM

To examine humeral retroversion in infants who sus-

tained brachial plexus birth palsy (BPBI) and suffered from an internal rotation contracture. Additionally, the role of the infraspinatus (IS) and subscapularis (SSc) muscles in the genesis of this bony deformation is explored.

METHODS

Bilateral magnetic resonance imaging (MRI) scans of 35 infants (age range: 2-7 mo old) with BPBI were retrospectively analyzed. Retroversion was measured according to two proximal axes and one distal axis (transepicondylar axis). The proximal axes were: (1) the perpendicular line to the borders of the articular surface (humeral centerline); and (2) the longest diameter through the humeral head. Muscle cross-sectional areas of the IS and SSc muscles were measured on the MRI-slides representing the largest muscle belly. The difference in retroversion was correlated with the ratio of muscle-sizes and passive external rotation measurements.

RESULTS

Retroversion on the involved side was significantly decreased, 1.0° vs 27.6° (1) and 8.5° vs 27.2° (2), ($P < 0.01$), as compared to the uninvolved side. The size of the SSc and IS muscles on the involved side was significantly decreased, 2.26 cm^2 vs 2.79 cm^2 and 1.53 cm^2 vs 2.19 cm^2 , respectively ($P < 0.05$). Furthermore, the muscle ratio (SSc/IS) at the involved side was significantly smaller compared to the uninvolved side ($P = 0.007$).

CONCLUSION

Even in our youngest patient population, humeral retroversion has a high likelihood of being decreased. Altered humeral retroversion warrants attention as a structural change in any child being evaluated for the treatment of an internal rotation contracture.

Key words: Humeral retroversion; Infants; Brachial plexus; Brachial plexus neuropathies; Shoulder; Humerus

© **The Author(s) 2018.** Published by Baishideng Publishing Group Inc. All rights reserved.

Core tip: This study examines humeral retroversion in infants who sustained neonatal brachial plexus palsy and suffered from an internal rotation contracture. The existing common treatment options all strive for better function of the upper extremity through an improved position of the hand in space. Therefore, a thorough understanding of the development of the pathogenesis of this injury is important. We found a significant reduction of humeral retroversion in our study group (mean difference, 26.8). When treatment becomes warranted and contralateral humeral version measurements greatly differ, a humeral derotational osteotomy may offer the best improvement regarding the hand position.

van de Bunt F, Pearl ML, van Essen T, van der Sluijs JA. Humeral retroversion and shoulder muscle changes in infants with internal rotation contractures following brachial plexus birth palsy. *World J Orthop* 2018; 9(12): 292-299
URL: <https://www.wjgnet.com/2218-5836/full/v9/i12/292.htm>
DOI: <https://dx.doi.org/10.5312/wjo.v9.i12.292>

INTRODUCTION

The most common musculoskeletal sequela of neurologic injury of brachial plexus birth palsy (BPBI) is an internal rotation contracture of the shoulder. This contracture is frequently associated with deformity of the glenohumeral joint^[1-5]. These bony deformities have been thought to be a consequence of abnormal muscular development^[6-8].

The internal rotation contracture secondary to BPBI has been associated with alterations of humeral retroversion^[9-12]. Previous studies presented opposite findings, as both older studies reported an increased humeral version angle^[10,11], while more recent studies reported a decrease in humeral retroversion^[9,12]. Normal humeral retroversion is greatest at birth and gradually decreases through adolescence^[13-15] to adult values averaging between 25-30 with well documented individual variation^[16]. One well-studied exception is the throwing athlete, for whom retroversion has been shown to be greater on the dominant throwing side, due to repetitive throwing that usually begins in early childhood^[17-21].

The existing common treatment options consist of soft tissue procedures (releases and tendon transfers) and bone realignment procedures (rotational osteotomy) with the aim to provide better function of the upper extremity through an improved position of the hand in space^[22-26]. This position is directly related to the humeral version angle. We studied humeral retroversion in 35 consecutive infants who were under evaluation for treatment of their internal rotation contractures secondary to unilateral BPBI in this retrospective observational study. Our main goal was to further elucidate the timing that these anatomic changes may occur; therefore, we included our youngest patient population. We hypothesized that the retroversion angle (RV-angle) on the involved side would be significantly decreased relative to the uninvolved side and that the difference would increase with age. Since the subscapularis (SSc) and infraspinatus (IS) muscles, are an agonist-antagonist muscle pair regarding humeral rotation, we hypothesized that an imbalance between these muscles would correlate with altered humeral version.

MATERIALS AND METHODS

In this retrospective observational study, we included 37 Magnetic resonance imaging (MRI) -scans from a consecutive series of infants (< 1 year old) with a unilateral BPBI. All infants were potential candidates for neurosurgical interventions because of the severity of the

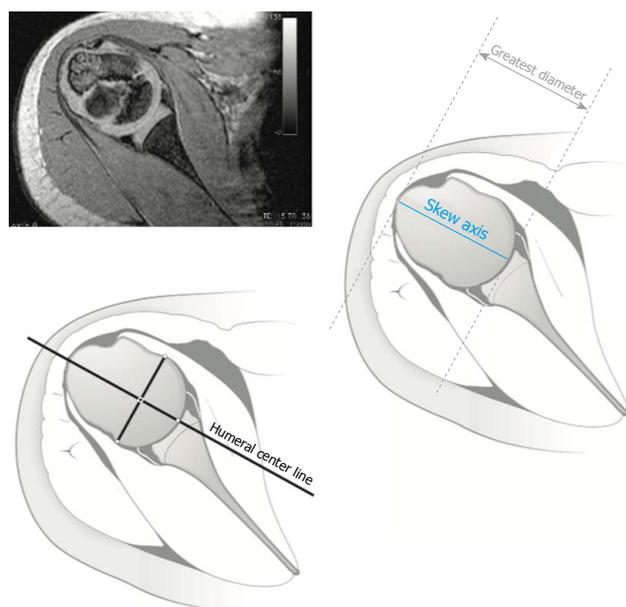


Figure 1 Schematic illustration of measurement parameters applied to a magnetic resonance imaging slice from the proximal part of the normal uninvolved, humerus. (Reproduced with modification from: Pearl ML, *et al.* Geometry of the proximal humeral articular surface in young children: a study to define normal and analyze the dysplasia due to brachial plexus birth palsy. *J Shoulder Elbow Surg* 2013; **22**: 1274-84. Reproduced with permission from Elsevier.)

neurological lesion. This study was IRB approved.

MRI studies were performed on a 1.5-T MRI-unit (Magnetom 1.5 T Vision; Siemens, Erlangen, Germany). A FISP three-dimensional pulse acquisition sequence (repetition time, 25 msec; time to echo, 10 msec; flip angle 40°) with ranges from 0.8 to 1.5 mm partitions was used to obtain images from both shoulders and upper arms, representing the full humerus and glenohumeral joint in the axial plane. All children were given pethidine, droperidol and chlorpromazine intramuscularly. During sedation, they were monitored by electrocardiograph, measurement of oxygen saturation, and by video. Children were not moved during the imaging protocol.

From these 37 studies, two were insufficient for completing our detailed measurement protocol, as one study did not capture the entire humerus and motion artifacts compromised the other study.

Our Radiology department anonymized the MRI studies before performing our measurement protocol; Digital Imaging and Communications in Medicine files were imported as a numerical database into Osirix (Pixmeo, Geneva, Switzerland). For humeral version measurements, axial plane slides from the involved and uninvolved side that to our best efforts represented the midpoint of the humeral head were selected. For the measurement of muscle dimensions, axial plane slides representing the largest cross-sectional area of the SSc muscle and infraspinatus muscle were selected and exported as TIFF files. The TIFF files were imported into Geometer's Sketchpad version 5.03 (KCP Technologies, Emeryville, CA, United States) for further retroversion

analyses. The region of interest tool available in Osirix was used for muscle cross-sectional area measurements. The Narakas classifications were assigned as described by Narakas^[27]. Passive external rotation was measured with the arm in the adducted position and the elbow by the side.

Measure of retroversion

Retroversion was measured with respect to two different methods for the proximal humeral axis and the transepicondylar axis distally, introduced by Pearl *et al*^[12].

The first proximal reference axis was chosen to provide continuity with earlier retroversion analysis performed in this specific patient group^[10,11]. This axis is conforming to the longest diameter through the humeral head. A line segment was created, which spanned the greatest distance from the periphery of the greater tuberosity to the medial articular surface and is labeled as the skew axis (SA) (Figure 1)^[2].

Retroversion was analyzed using the humeral center-line (HCL) as the proximal axis (Figure 1). This is a commonly used axis in various retroversion studies^[19,28-32]. The HCL represents the perpendicular projection from the margins of the articular surface.

Based on the literature, retroversion of the humeral head is shown as a positive value and anteversion is shown as a negative value. Two investigators performed the humeral version measurements.

Surface area measurements

Cross-sectional areas of the IS and SSc muscles were measured using the closed region-of-interest polygon tool in Osirix (Pixmeo). The MRI slides depicting the largest muscle bellies were identified for measurement of this cross-sectional area. Muscle size was determined by the muscle cross-sectional area in cm² and muscle percentage relative to the corresponding muscle at the uninvolved side. Furthermore, the ratio of the SSc and IS muscle (SSc/IS) was calculated to compare muscle balance between both sides and correlate these with the ΔRV-angle.

Analysis

Statistical analysis was performed using SPSS software (version 22.0; SPSS Inc., Chicago, IL, United States). The distribution analysis showed an approximately normal distribution.

Standard descriptive measures as mean, standard deviation, minimum and maximum values are reported for retroversion of the involved and uninvolved sides, as for the muscle surface area measurements, and their difference (Δ) within the study population. Pearson product-moment or Spearman rank correlation coefficients are estimated between each of these and passive external rotation and Narakas classification, as appropriate, based on the underlying distribution and type of the data. Paired data, such as involved vs uninvolved measurements regarding retroversion and muscle cross-sectional area measurements made on the same

Table 1 Demographics

Subject	Narakas	Age (mo)	External rotation (passive) (°)	Retroversion involved (HCL) (°)	Retroversion involved (SA) (°)	Retroversion uninvolved (HCL) (°)	Retroversion uninvolved (SA) (°)
1	3	2.6	-15	7.665	11.25	26.4	26.315
2	1	3.1	-5	-9.16	11.045	23.18	13.485
3	1	3.2	-40	-17.125	4.04	18.65	17.05
4	3	3.2	-30	14.175	23.395	30.56	31.865
5	3	3.3	0	-7.05	6.67	31.23	32.85
6	3	3.4	-10	-24.74	-19.26	41.72	31.705
7	3	3.4	0	7.67	7.905	30.145	29.165
8	3	3.5	-20	35.595	35.015	27.295	31.23
9	2	3.5	-5	-10.885	1.615	24.17	23.905
10	1	3.5	-20	4.54	2.05	32.21	26.49
11	3	3.6	-20	1.99	5.695	43.55	36.11
12	1	3.6	-20	3.6	22.565	54.905	47.955
13	3	3.8	-25	1.595	9.425	29.355	36.42
14	1	4.0	-5	-6.715	3.44	29.115	28.165
15	2	4.1	-15	-13.53	-1.035	21.59	25.605
16	1	4.1	-15	14.975	9.85	25.575	21.24
17	3	4.5	-25	0.065	-2.075	19.47	19.995
18	3	4.5	-45	24.195	20.195	34.19	34.55
19	1	4.5	-10	-4.115	6.1	24.305	20.175
20	2	4.6	-30	-7.205	11.675	13.465	14.06
21	3	4.6	-10	-3.14	7.29	15.445	12.14
22	1	4.7	-20	4.125	18.195	23.045	30.385
23	1	4.7	-20	-20.83	1.9	21.85	30.085
24	1	4.8	-40	4.875	9.95	15.655	20.11
25	3	4.9	-40	8.935	9.525	18.805	11.765
26	1	5.0	-15	38.24	33.53	20.055	15.945
27	1	5.0	0	-8.86	4.405	24.85	21.6
28	1	5.0	-15	-30.23	-20.135	38.975	23.31
29	1	5.0	-10	24.725	25.535	32.98	39.03
30	1	5.1	-5	8.79	10.05	20.115	-2.295
31	1	5.4	-20	-28.55	-11.965	47.445	39.185
32	3	5.6	-35	3.385	6.45	30.395	27.485
33	3	5.9	-15	-16.805	11.66	18.085	14.5
34	2	5.9	-30	11.89	7.225	28.56	35.075
35	1	6.5	-10	17.315	14.43	31.08	22.5
Mean		4.3	-18.3	0.8	8.5	27.7	25.4
Standard deviation		0.9	12	16.1	11.7	9.2	9.8
Minimum		2.6	-45	-30.23	-20.135	13.465	-2.295
Maximum		6.5	0	38.24	35.015	54.905	47.955

HCL: Humeral center-line; SA: Skew axis.

subject, were compared using paired t- or paired-samples Wilcoxon's signed-rank tests, as appropriate. Inter-rater reliability assessment by Intraclass correlations coefficient (ICC) was performed. A Bland-Altman plot was created to visualize potential differences in retroversion measuring methods^[33].

RESULTS

The 35 children included in our study had a mean age of 4.3 mo (range of 2.1-6.5 mo), and they were classified according to the Narakas classification: Narakas I : 18 cases; Narakas II : 4 cases; Narakas III : 15 cases. Internal rotation contractures varied from -45° to 12°, with a mean of -18°, measured as passive external rotation with the elbow by the side (Table 1).

Humeral retroversion by HCL

Retroversion measured according to the HCL and the

transepicondylar axis was significantly decreased on the involved side as measured by both observers. Mean RV-angles were 0.8° vs 27.7° ($P < 0.001$). Paired differences averaged 26.8°, with a range from -18.4° to 77.8°. Figure 2 shows the distribution of the measurements. In two patients, retroversion increased on the involved side (Table 1). Age did not correlate with a decrease in humeral retroversion ($r = -0.108$, $P = 0.538$).

Humeral retroversion by SA

Retroversion measured according to the SA and the transepicondylar axis was also significantly decreased on the involved side, as measured by both observers. Mean RV-angles were 8.5° vs 25.4° ($P < 0.001$). Paired differences averaged 17.5°, with a range from -22.2° to 53.3°. Figure 3 shows the distribution of measurements. In five patients, retroversion was increased on the involved side (Table 1). Age was again not correlated with a decrease in humeral retroversion ($r = -0.120$, $P =$

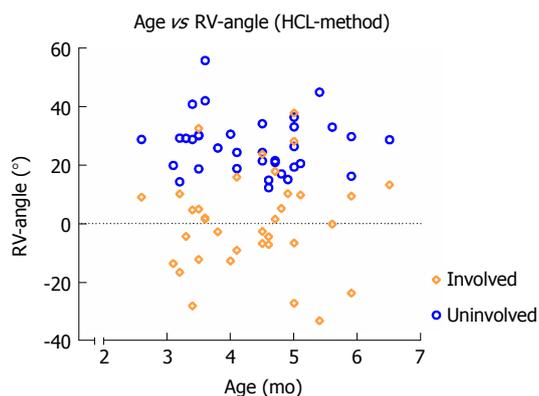


Figure 2 The distribution among measurements using the humeral center line as a proximal axis. HCL: Humeral center line; RV-angle: Retroversion angle.

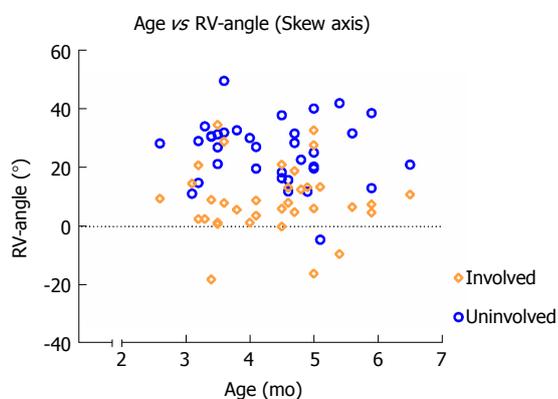


Figure 3 The distribution among measurements using the skew axis as a proximal axis. In the deformed humeral head, the skew axis yields systematically higher values compared to the humeral center line. RV-angle: Retroversion angle.

0.492).

Muscle surface area

Both muscles were significantly smaller on the involved side. The IS muscle measured a mean surface area of 2.35 cm² vs 2.84 cm² (83%) ($P < 0.001$), and the SSC muscle was 1.56 cm² vs 2.20 cm² (70%) ($P < 0.001$).

Furthermore, the muscle ratio (SSc/IS) on the involved side was significantly smaller compared to the uninvolved side ($P = 0.007$). In Table 2, the results of the muscle cross-sectional area measurements are summarized.

Correlations

Pearson’s product correlation tests were performed for the retroversion measurements, the Δ RV-angle and the muscle area ratios and muscle surface area measurements, however no significant correlations were found on the involved side. When correlating age with decrease of retroversion, the Spearman Rho test was performed for retroversion measurement and Narakas’ score and passive external rotation, no significant correlations were found ($P > 0.05$).

HCL method vs SA

For retroversion measured by HCL, the ICC for interrater reliability on the involved side was 0.934 (95%CI: 0.863-0.967; $P < 0.001$). The ICC for interrater reliability on the uninvolved side was 0.889 (95%CI: 0.747-0.948; $P < 0.001$). For retroversion measured using the SA, the ICC for interrater reliability on the involved side was 0.934 (95%CI: 0.897-0.970; $P < 0.001$). The ICC for interrater reliability on the uninvolved side was 0.923 (95%CI: 0.853-0.960; $P < 0.001$).

The distribution of measurements was larger on the involved side (Figure 4). Both measurement methods yielded comparable results in the uninvolved shoulder. However, the SA yielded systematically higher values in the deformed humeral head compared to the HCL.

DISCUSSION

We found a significant reduction of humeral retroversion on the involved side compared to the uninvolved side in a consecutive series of patients with internal rotation contractures secondary to BPBI. Additionally, the size of the SSc and IS muscles on the involved side was significantly decreased, as was the muscle ratio (SSc/IS) on the involved side compared to the uninvolved side.

Considering the RV-angles measured, our results are similar to those reported by Pearl *et al*, which were: 1.8° and 5.8° compared to 20.2° and 18.9°, respectively, depending on the method of measurement. However, the mean age of the study groups differed considerably, 3.2 years old vs 4.3 mo old. Our results suggest that declined humeral version is not something these children slowly grow into. The altered humeral version angle may already develop within the first weeks after birth, when the humerus is probably most prone to altered development caused by altered muscle forces gripping the humeral head. This is supported by the lack of significant correlation found between age and decreased retroversion on the involved side in both studies.

Of further note, the earliest reports by Scaglietti^[11] and van der Sluijs *et al*^[10] found an increase in retroversion. Scaglietti’s study was in a very different era of imaging technology and presented his observations with little quantitative data. van der Sluijs *et al*^[10] utilized MRI, but nearly two decades ago in a somewhat older age group, when current software tools were not available for image analysis, and the lesser image quality might have influenced measurements. Perhaps these methodological differences explain these contradictory findings.

Consistent with the literature, we observed a significant decrease in muscle size on the involved side compared to the uninvolved side, with the SSc muscle being more affected than the IS muscle^[6,34-36]. However, no significant correlation between the muscle ratio (SSc/IS) and the humeral RV-angle was observed. Nonetheless, the reduction in muscle ratio does not support the theory that the internal rotators overpower the injured (paralyzed) external rotators, but suggests

Table 2 Main results of the muscle cross-sectional area measurements

Muscle area, cm ²	Mean - involved	Mean - uninvolved	P value
Subscapularis muscle	1.56 ± 0.315	2.20 ± 0.372	< 0.001
Infraspinatus muscle	2.35 ± 0.520	2.84 ± 0.495	< 0.001
Ratio	68.51 ± 16.90	78.88 ± 15.45	0.007

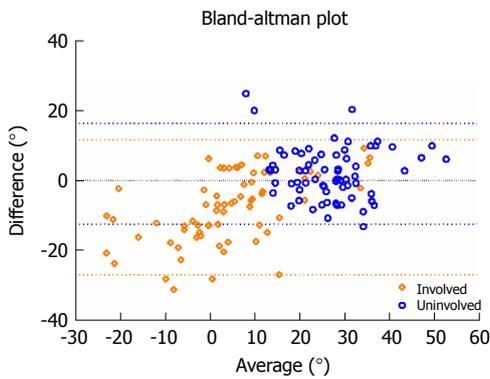


Figure 4 The distribution of measurement in the involved shoulder is larger than on the uninvolved side, indicating measurement differences between the skew axis and humeral center line are larger on the involved side. The blue and orange dotted lines represent the 95% limits of agreement.

that failure of the SSc to grow or develop may result in a contracted SSc, which restricts external rotation.

Another theory could be that the changes in humeral retroversion are partially related to injured muscles outside of the rotator cuff, perhaps those with at least some innervation outside of the original zone of injury. Further study of other muscles is warranted, looking for evidence as to whether they were also injured resulting in impaired growth^[7,37], or whether they recovered so strongly that they overwhelmed their antagonists or are used differently in children with varying levels of recovery.

In addition, animal studies have shown that impaired longitudinal muscle growth and strength imbalance mechanisms are capable of producing shoulder deformities and impaired growth to a somewhat greater extent than muscle imbalance^[8,38-41]. However, this has not yet been related to altered humeral version. For example, impaired growth and increased stiffness of the SSc muscle fibers may have a significant effect on humeral version development. In combination with other internal rotator muscles such as the pectoralis muscle, mechanical stiffness of these muscle fibers may not be directly related to cross-sectional muscle area measurements.

Further research is necessary to elucidate a causal relationship between those mechanisms and shoulder deformities, concerning both the humerus and glenoid, which will help guide clinical treatment decisions for BPBI.

This study has several limitations. The measurements made were based on axial slices of the humerus; measurements made from a 3D-reconstruction, as those performed by Sheehan and others, would have the potential for minimizing errors related to patient

positioning and inconsistent image acquisition. In our studied age group, the humeral head and epicondylar axis are mostly cartilaginous, making 3D-reconstruction of the humeral anatomy much more challenging than in a skeletally mature subject. While the software tools currently exist, they are labor intensive and extremely difficult to implement in clinical practice. Therefore, we chose to utilize methods often used in our clinic setting and shown in a prior publication^[12].

Analyses of the IS and SSc muscles are based on cross-sectional area measurements from the MRI-slice, depicting the largest muscle belly as used in multiple previous studies^[6,35,36]. Capturing the full volume of both muscles would likely have been more informative; however, such software tools were not available to us. Furthermore, muscle thickness was only assessed for the IS and SSc muscles, and the measurement of other external and internal rotator muscles may offer additional insight into muscle behavior and its effect on humeral retroversion in this population.

The most common sequel and focus of surgical intervention in children with BPBI is an internal rotation contracture at the shoulder. These surgical interventions all aim for better function through an improved position of the hand in space. Humeral version undeniably affects hand functionality because with all other factors being equal, decreased humeral version results in an increase of the severity of the clinical presentation of an internal rotation contracture. A large reduction in humeral retroversion at a very young age could be a predictor (or an argument when apparent at an older age) for the necessity of a humeral derotational osteotomy to provide adequate improvement of hand and possibly elbow function. Furthermore, this study shows that secondary osseous changes can occur within several months in this patient population. A prospective study analyzing possible changes in humeral version in this patient population over time would be of interest, as it seems through these results and results from recent studies that changes in humeral version occur early, but that they may not change much after that.

In conclusion, humeral retroversion has a high likelihood of being significantly decreased in this patient population. These findings are relevant for any child under consideration for surgical intervention aiming to improve external rotation, since all other factors being equal, decreased humeral retroversion results in an increased severity of the clinical presentation of an internal rotation contracture. We measured these changes in infants 2-7 mo old and found that altered humeral development

can occur very early in life in a population where internal rotation contractures are apparent.

ARTICLE HIGHLIGHTS

Research background

The existing common treatment options for children suffering from brachial plexus birth palsy all strive for better function of the upper extremity through an improved position of the hand in space. This position is directly related to the humeral version angle.

Research motivation

Since earlier studies did not reveal a correlation between age and decreased retroversion on the involved side, the question remained at what age this anatomic change may occur.

Research objectives

Our objective was to elucidate the timing that decreased retroversion may occur; therefore, we included our youngest patient population (2-7 mo old).

Research methods

We measured humeral version relative to two proximal axes and one distal axis (transepicondylar axis). The proximal axes were: (1) the perpendicular line to the borders of the articular surface (humeral centerline), and (2) the longest diameter through the humeral head. Additionally, cross-sectional areas of the infraspinatus (IS) and subscapularis (SSc) muscles were measured. The difference in retroversion was correlated with the ratio of muscle sizes.

Research results

Retroversion on the involved side was significantly decreased, 1.0° vs 27.6° (1) and 8.5° vs 27.2° (2), ($P < 0.01$), as compared to the uninvolved side. SSc and IS muscle size on the involved side was significantly decreased, 2.26 cm^2 vs 2.79 cm^2 and 1.53 cm^2 vs 2.19 cm^2 , respectively ($P < 0.05$). Additionally, muscle ratio (SSc/IS) on the involved side was significantly smaller compared to the uninvolved side ($P = 0.007$), but was not related to alterations in humeral version.

Research conclusions

Our results show that altered humeral development can occur very early in life in a population where internal rotation contractures are apparent.

Research perspectives

A large reduction in humeral retroversion at a very young age could be a predictor (or an argument when apparent at an older age), for the necessity of a humeral derotational osteotomy, to provide adequate improvement of hand and possibly elbow function. A prospective study analyzing changes in humeral version over time would be of interest to assess the predictive value of decreased retroversion at such a young age, concerning various treatment options (soft-tissue and bony).

REFERENCES

- 1 **Pearl ML**, Edgerton BW. Glenoid deformity secondary to brachial plexus birth palsy. *J Bone Joint Surg Am* 1998; **80**: 659-667 [PMID: 9611026 DOI: 10.2106/00004623-199805000-00006]
- 2 **Pearl ML**, Woolwine S, van de Bunt F, Merton G, Burchette R. Geometry of the proximal humeral articular surface in young children: a study to define normal and analyze the dysplasia due to brachial plexus birth palsy. *J Shoulder Elbow Surg* 2013; **22**: 1274-1284 [PMID: 23478467 DOI: 10.1016/j.jse.2012.12.031]
- 3 **Kozin SH**. Correlation between external rotation of the glenohumeral joint and deformity after brachial plexus birth palsy. *J Pediatr Orthop* 2004; **24**: 189-193 [PMID: 15076606 DOI: 10.1097/01241398-200403000-00011]
- 4 **Waters PM**, Smith GR, Jaramillo D. Glenohumeral deformity

- secondary to brachial plexus birth palsy. *J Bone Joint Surg Am* 1998; **80**: 668-677 [PMID: 9611027 DOI: 10.2106/00004623-199805000-00007]
- 5 **van der Sluijs JA**, van Ouwerkerk WJ, de Gast A, Wuisman PI, Nollet F, Manoliu RA. Deformities of the shoulder in infants younger than 12 months with an obstetric lesion of the brachial plexus. *J Bone Joint Surg Br* 2001; **83**: 551-555 [PMID: 11380130 DOI: 10.1302/0301-620x.83b4.11205]
- 6 **Waters PM**, Monica JT, Earp BE, Zurakowski D, Bae DS. Correlation of radiographic muscle cross-sectional area with glenohumeral deformity in children with brachial plexus birth palsy. *J Bone Joint Surg Am* 2009; **91**: 2367-2375 [PMID: 19797571 DOI: 10.2106/JBJS.H.00417]
- 7 **Nikolaou S**, Peterson E, Kim A, Wylie C, Cornwall R. Impaired growth of denervated muscle contributes to contracture formation following neonatal brachial plexus injury. *J Bone Joint Surg Am* 2011; **93**: 461-470 [PMID: 21368078 DOI: 10.2106/JBJS.J.00943]
- 8 **Soldado F**, Fontecha CG, Marotta M, Benito D, Casaccia M, Mascarenhas VV, Zlotolow D, Kozin SH. The role of muscle imbalance in the pathogenesis of shoulder contracture after neonatal brachial plexus palsy: a study in a rat model. *J Shoulder Elbow Surg* 2014; **23**: 1003-1009 [PMID: 24388715 DOI: 10.1016/j.jse.2013.09.031]
- 9 **Sheehan FT**, Brochard S, Behnam AJ, Alter KE. Three-dimensional humeral morphologic alterations and atrophy associated with obstetrical brachial plexus palsy. *J Shoulder Elbow Surg* 2014; **23**: 708-719 [PMID: 24291045 DOI: 10.1016/j.jse.2013.08.014]
- 10 **van der Sluijs JA**, van Ouwerkerk WJ, de Gast A, Wuisman P, Nollet F, Manoliu RA. Retroversion of the humeral head in children with an obstetric brachial plexus lesion. *J Bone Joint Surg Br* 2002; **84**: 583-587 [PMID: 12043783 DOI: 10.1302/0301-620x.84b4.12243]
- 11 **Scaglietti O**. The obstetrical shoulder trauma. *Surg Gynecol Obstet* 1938. pp. 868-877
- 12 **Pearl ML**, Batech M, van de Bunt F. Humeral Retroversion in Children with Shoulder Internal Rotation Contractures Secondary to Upper-Trunk Neonatal Brachial Plexus Palsy. *J Bone Joint Surg Am* 2016; **98**: 1988-1995 [PMID: 27926680 DOI: 10.2106/JBJS.15.01132]
- 13 **Krahl VE**. The torsion of the humerus; its localization, cause and duration in man. *Am J Anat* 1947; **80**: 275-319 [PMID: 20296010 DOI: 10.1002/aja.1000800302]
- 14 **Edelson G**. The development of humeral head retroversion. *J Shoulder Elbow Surg* 2000; **9**: 316-318 [PMID: 10979528 DOI: 10.1067/mse.2000.106085]
- 15 **Cowgill LW**. Humeral torsion revisited: a functional and ontogenetic model for populational variation. *Am J Phys Anthropol* 2007; **134**: 472-480 [PMID: 17657784 DOI: 10.1002/ajpa.20689]
- 16 **Edelson G**. Variations in the retroversion of the humeral head. *J Shoulder Elbow Surg* 1999; **8**: 142-145 [PMID: 10226966 DOI: 10.1016/s1058-2746(99)90007-1]
- 17 **Yamamoto N**, Itoi E, Minagawa H, Urayama M, Saito H, Seki N, Iwase T, Kashiwaguchi S, Matsuura T. Why is the humeral retroversion of throwing athletes greater in dominant shoulders than in nondominant shoulders? *J Shoulder Elbow Surg* 2006; **15**: 571-575 [PMID: 16979051 DOI: 10.1016/j.jse.2005.06.009]
- 18 **Whiteley R**, Adams R, Ginn K, Nicholson L. Playing level achieved, throwing history, and humeral torsion in Masters baseball players. *J Sports Sci* 2010; **28**: 1223-1232 [PMID: 20694888 DOI: 10.1080/02640414.2010.498484]
- 19 **Chant CB**, Litchfield R, Griffin S, Thain LM. Humeral head retroversion in competitive baseball players and its relationship to glenohumeral rotation range of motion. *J Orthop Sports Phys Ther* 2007; **37**: 514-520 [PMID: 17939610 DOI: 10.2519/jospt.2007.2449]
- 20 **Myers JB**, Oyama S, Rucinski TJ, Creighton RA. Humeral retrotorsion in collegiate baseball pitchers with throwing-related upper extremity injury history. *Sports Health* 2011; **3**: 383-389

- [PMID: 23016031 DOI: 10.1177/1941738111410636]
- 21 **Osbah DC**, Cannon DL, Speer KP. Retroversion of the humerus in the throwing shoulder of college baseball pitchers. *Am J Sports Med* 2002; **30**: 347-353 [PMID: 12016074 DOI: 10.1177/03635465020300030801]
 - 22 **Pearl ML**, Edgerton BW, Kazimiroff PA, Burchette RJ, Wong K. Arthroscopic release and latissimus dorsi transfer for shoulder internal rotation contractures and glenohumeral deformity secondary to brachial plexus birth palsy. *J Bone Joint Surg Am* 2006; **88**: 564-574 [PMID: 16510824 DOI: 10.2106/JBJS.D.02872]
 - 23 **Kozin SH**, Boardman MJ, Chafetz RS, Williams GR, Hanlon A. Arthroscopic treatment of internal rotation contracture and glenohumeral dysplasia in children with brachial plexus birth palsy. *J Shoulder Elbow Surg* 2010; **19**: 102-110 [PMID: 19664938 DOI: 10.1016/j.jse.2009.05.011]
 - 24 **Waters PM**, Bae DS. The effect of derotational humeral osteotomy on global shoulder function in brachial plexus birth palsy. *J Bone Joint Surg Am* 2006; **88**: 1035-1042 [PMID: 16651578 DOI: 10.2106/JBJS.E.00680]
 - 25 **Gilbert A**, Brockman R, Carliz H. Surgical treatment of brachial plexus birth palsy. *Clin Orthop Relat Res* 1991; : 39-47 [PMID: 1847671 DOI: 10.1097/00003086-199103000-00005]
 - 26 **Kirkos JM**, Kyrkos MJ, Kapetanios GA, Haritidis JH. Brachial plexus palsy secondary to birth injuries. *J Bone Joint Surg Br* 2005; **87**: 231-235 [PMID: 15736749 DOI: 10.1302/0301-620X.88B4.17641]
 - 27 **Birch R**. Obstetric brachial plexus palsy. *J Hand Surg Br* 2002; **27**: 3-8 [PMID: 11895337 DOI: 10.1054/jhsb.2001.0722]
 - 28 **Boileau P**, Bicknell RT, Mazzoleni N, Walch G, Urien JP. CT scan method accurately assesses humeral head retroversion. *Clin Orthop Relat Res* 2008; **466**: 661-669 [PMID: 18264854 DOI: 10.1007/s11999-007-0089-z]
 - 29 **DeLude JA**, Bicknell RT, MacKenzie GA, Ferreira LM, Dunning CE, King GJ, Johnson JA, Drosdowech DS. An anthropometric study of the bilateral anatomy of the humerus. *J Shoulder Elbow Surg* 2007; **16**: 477-483 [PMID: 17363290 DOI: 10.1016/j.jse.2006.09.016]
 - 30 **Harrold F**, Wigderowitz C. A three-dimensional analysis of humeral head retroversion. *J Shoulder Elbow Surg* 2012; **21**: 612-617 [PMID: 21783384 DOI: 10.1016/j.jse.2011.04.005]
 - 31 **Hernigou P**, Duparc F, Hernigou A. Determining humeral retroversion with computed tomography. *J Bone Joint Surg Am* 2002; **84-A**: 1753-1762 [PMID: 12377904 DOI: 10.2106/00004623-200306000-00035]
 - 32 **Matsumura N**, Ogawa K, Kobayashi S, Oki S, Watanabe A, Ikegami H, Toyama Y. Morphologic features of humeral head and glenoid version in the normal glenohumeral joint. *J Shoulder Elbow Surg* 2014; **23**: 1724-1730 [PMID: 24862249 DOI: 10.1016/j.jse.2014.02.020]
 - 33 **Bland JM**, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986; **1**: 307-310 [PMID: 2868172 DOI: 10.1016/S0140-6736(86)90837-8]
 - 34 **Hogendoorn S**, van Overvest KL, Watt I, Duijsens AH, Nelissen RG. Structural changes in muscle and glenohumeral joint deformity in neonatal brachial plexus palsy. *J Bone Joint Surg Am* 2010; **92**: 935-942 [PMID: 20360518 DOI: 10.2106/JBJS.I.00193]
 - 35 **Van Gelein Vitranga VM**, Jaspers R, Mullender M, Ouwkerk WJ, Van Der Sluijs JA. Early effects of muscle atrophy on shoulder joint development in infants with unilateral birth brachial plexus injury. *Dev Med Child Neurol* 2011; **53**: 173-178 [PMID: 20846159 DOI: 10.1111/j.1469-8749.2010.03783.x]
 - 36 **Pöyhkä TH**, Nietosvaara YA, Remes VM, Kirjavainen MO, Peltonen JI, Lamminen AE. MRI of rotator cuff muscle atrophy in relation to glenohumeral joint incongruence in brachial plexus birth injury. *Pediatr Radiol* 2005; **35**: 402-409 [PMID: 15635469 DOI: 10.1007/s00247-004-1377-3]
 - 37 **Einarsson F**, Hultgren T, Ljung BO, Runesson E, Fridén J. Subscapularis muscle mechanics in children with obstetric brachial plexus palsy. *J Hand Surg Eur Vol* 2008; **33**: 507-512 [PMID: 18687840 DOI: 10.1177/1753193408090764]
 - 38 **Crouch DL**, Hutchinson ID, Plate JF, Antoniono J, Gong H, Cao G, Li Z, Saul KR. Biomechanical Basis of Shoulder Osseous Deformity and Contracture in a Rat Model of Brachial Plexus Birth Palsy. *J Bone Joint Surg Am* 2015; **97**: 1264-1271 [PMID: 26246261 DOI: 10.2106/JBJS.N.01247]
 - 39 **Li Z**, Barnwell J, Tan J, Koman LA, Smith BP. Microcomputed tomography characterization of shoulder osseous deformity after brachial plexus birth palsy: a rat model study. *J Bone Joint Surg Am* 2010; **92**: 2583-2588 [PMID: 21048177 DOI: 10.2106/JBJS.I.01660]
 - 40 **Li Z**, Ma J, Apel P, Carlson CS, Smith TL, Koman LA. Brachial plexus birth palsy-associated shoulder deformity: a rat model study. *J Hand Surg Am* 2008; **33**: 308-312 [PMID: 18343282 DOI: 10.1016/j.jhsa.2007.11.017]
 - 41 **Soldado F**, Benito-Castillo D, Fontecha CG, Barber I, Marotta M, Haddad S, Menendez ME, Mascarenhas VV, Kozin SH. Muscular and glenohumeral changes in the shoulder after brachial plexus birth palsy: an MRI study in a rat model. *J Brachial Plex Peripher Nerve Inj* 2012; **7**: 9 [PMID: 23217052 DOI: 10.1186/1749-7221-7-9]

P- Reviewer: Emara KM, Wyatt MC **S- Editor:** Dou Y
L- Editor: Filipodia **E- Editor:** Bian YN



Metallosis following a clip breakage in a total knee arthroplasty implant: A case report

Ahmed Isam Saad, Shafiq Arif Shahban, Richard Fernandes

Ahmed Isam Saad, Shafiq Arif Shahban, Richard Fernandes, Good Hope Hospital Part of the University Hospital Birmingham, Birmingham B75 7RR, United Kingdom

ORCID number: Ahmed Isam Saad (0000-0002-5796-069X); Shafiq Arif Shahban (0000-0002-8807-8026); Richard Fernandes (0000-0002-5837-4385).

Author contributions: Saad AI, Shahban SA and Fernandes R contributed equally to this work, they designed the research and contributed to writing the paper equally.

Informed consent statement: Informed consent has been taken from this patient and form provided with manuscript.

Conflict-of-interest statement: No conflicts of interest.

CARE Checklist (2016) statement: The CARE checklist (2016) has been added to the content of this manuscript.

Open-Access: This article is an open-access article which was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>

Manuscript source: Unsolicited manuscript

Corresponding author to: Ahmed Isam Saad, MBBS, Surgeon, Good Hope Hospital Part of the University Hospital Birmingham, West Midlands, Birmingham B16 8EQ, United Kingdom. ahmed.saad3@nhs.net
Telephone: +44-740-5775343
Fax: +44-121-3712000

Received: October 2, 2018

Peer-review started: October 2, 2018

First decision: November 16, 2018

Revised: November 22, 2018

Accepted: December 13, 2018

Article in press: December 13, 2018

Published online: December 18, 2018

Abstract

BACKGROUND

Metallosis describes the build-up of metal debris in the soft tissues after a period of metal on metal articulation. This debris can be asymptomatic or lead to catastrophic implant failure, which can present acutely, as in this case, or over a period of time. This report highlights how a metal clip used to hold the polyethylene liner to the tibial base plate broke 5 years after implantation, dislodged from its original position and went on to cause post-operative knee metallosis.

CASE SUMMARY

We present a case of a 63 year old lady admitted to our unit with an acute onset of right knee pain on top of a previous right total knee replacement. There was no associated trauma and examination revealed an erythematous, swollen and tender right knee. Blood investigations went on to display significantly raised inflammatory markers, raising the suspicion of a septic joint. This patient was taken to theatre for a knee arthrotomy and lavage of what was thought to be a septic joint when she was found to have extensive knee metallosis. On further inspection the metal clip, normally used to secure the polyethylene insert to the tibial base plate, had broken, dislodged, and had triggered this response. After the initial washout, this lady went back to theatre, once the appropriate implants were in stock, for an exchange of liner and metal clip.

CONCLUSION

This case highlights this very rare complication which has never been reported in the literature and the success of this patient's management.

Key words: Case report; Metallosis; Total knee replacement; Vanguard[®]

© **The Author(s) 2018.** Published by Baishideng Publishing Group Inc. All rights reserved.

Core tip: Metallosis describes the build-up of metal debris in the soft tissues after a period of metal on metal articulation. This can present acutely, as in this case, or gradually. This case report highlights how a metal clip used to hold the polyethylene liner to the tibial base plate broke 5 years after implantation, dislodged from its original position and went on to cause post-operative knee metallosis. The success to this patient's management came from thorough debridement, and replacement of the components involved.

Saad AI, Shahban SA, Fernandes R. Metallosis following a clip breakage in a total knee arthroplasty implant: A case report. *World J Orthop* 2018; 9(12): 300-303

URL: <https://www.wjgnet.com/2218-5836/full/v9/i12/300.htm>

DOI: <https://dx.doi.org/10.5312/wjo.v9.i12.300>

INTRODUCTION

Metallosis is a rare condition that has been recognised to affect both knee and hip arthroplasties. The most common cause leading to this malady is abrasive wear of the polyethylene component, inadvertently allowing two or more of the metal components to come into contact. This subsequently leads to a serious and debilitating synovial reaction.

Though the majority of cases documented in the literature of metallosis involve the wear of the polyethylene component; we present a rare and interesting case of metallosis in the knee following breakage of the metal clip used to hold the polyethylene insert of a Vanguard® implant in place. This consequently allowed the femoral and tibial components to come into contact leading to the acute metal induced synovitis.

CASE PRESENTATION

Case report

A 63 years old lady had a right total knee replacement (TKR) in 2013 using the Vanguard® knee system - Biomet implant. She was admitted into hospital in March 2018 - approximately five years following her initial TKR. She presented with an insidious and acute onset of worsening right knee pain and swelling, not associated with any trauma. The pain was affecting her mobility, limiting her ability to weight bear on that joint.

On clinical assessment, she had an erythematous and fluctuant right knee with a moderate joint effusion. Along with this, she had a tender joint line with a limited range of movement. There was no evidence of wound breakdown, equally in 2013 following her primary procedure, she had an uncomplicated recovery period. She had a core body temperature of 37.3 °C, with no accompanying fevers or rigors, and the rest of her

physiological markers were unremarkable.

Her initial blood investigations revealed significantly raised inflammatory markers with a white cell count (WCC) of $20.27 \times 10^9/L$, neutrophils of $16.68 \times 10^9/L$ and C - reactive protein (CRP) of 186 mg/L, suggesting an acute infection. Radiographs of the knee showed a relatively well positioned in-situ TKR, with no evidence of loosening, with the possibility of a joint effusion (Figure 1A and B).

Given this patient's history, examination and biochemical findings, a right knee septic arthritis could not be excluded, and as such she was taken to theatre for a knee arthrotomy with a view to debride the joint, and potentially replacement of the polyethylene liner.

After the initial arthrotomy was made, significant purulent, dark coloured fluid extruded from the joint. The knee joint was formally opened and at this point no pus was seen, however there was a significant amount of metallosis debris deeply embedded into the soft tissues surrounding the knee prostheses (Figure 2A). On further inspection, it was clear that the metal clip which is normally used to secure the polyethylene insert to the tibial base plate had broken and dislodged (Figures 2B and C). Despite this broken metal clip, the polyethylene liner was still in its original position, and on further examination the femoral, tibial and patella implants were all well fixed with no evidence of loosening. There was also no evidence of significant macroscopic wear of the femoral and tibial components.

The broken metal clip was retrieved successfully and in whole (part being dislodged and part being well fixed in the polyethylene liner). The Vanguard® TKR system is no longer used in our trust, and consequently we were unable to replace the liner and metal clip. This lady therefore went on to have a thorough soft tissue debridement of her metallosis and lavage with copious normal saline solution. She later had a second staged procedure (after a total of 18 d) at which point we were able to obtain the correct implants, and thus provide her with a new polyethylene liner and metal clip to secure it in place. In the interim, between stages, she was prescribed a course of two grams of intravenous flucloxacillin antibiotics (to complete a six week course) and was restricted with her weight bearing, to prevent polyethylene liner displacement.

Superficial and deep tissue samples from the time of her 1st procedure did not grow any organisms. The histology report demonstrated areas of black necrosis with reactive fibrosis, a giant cell foreign body reaction triggered by black, irregular metallic particles, confirming the diagnosis of metallosis.

OUTCOME AND FOLLOW UP

Post-operatively, the patient's inflammatory markers started to improve with a fall in the CRP to 52 mg/L and WCC of 12×10^9 . There was also marked improvement in her symptoms, pain and range of movement of the knee. She was later discharged whilst being able to fully



Figure 1 Initial radiographs of the right knee. A: Anterior-posterior radiograph of the right knee; B: Lateral radiograph of the right knee.

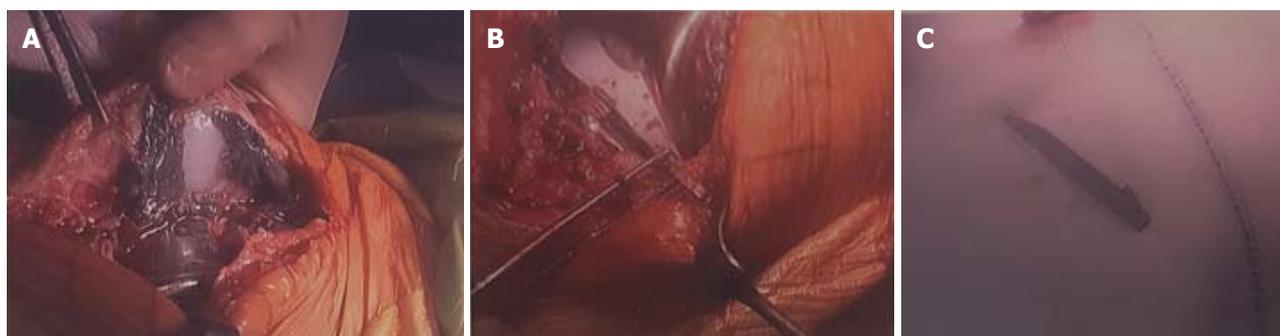


Figure 2 Intraoperative images of the soft tissues surrounding the *in-situ* total knee replacement. A: Intraoperative Image of extensive soft tissue metallosis; B, C: The retrieved broken metal clip.

weight bear and with a much improved knee. At the six week stage, in the outpatient clinic, she had complete resolution of her symptoms and was happily discharged from clinic.

DISCUSSION

Metallosis is an uncommon synovial reaction that can lead to serious complications and almost always requires revision surgery. It is therefore critical to understand the causes that lead to this condition. Avoidance of this essentially comes down to trying to ensure that the individual metal components of any part of the prosthetic joint are not allowed to come into contact and abrade against each other. Most case reports in the literature document the development of metallosis following significant wear of the interposed polyethylene component^[1]. In this report we found no significant wear of the polyethylene insert, but rather, ensuing metallosis which was allowed to occur due a metal clip which had broken and dislodged, allowing for metal-on-metal (MOM) abrasion of the components.

As the inflammation progresses, often over a prolonged period of time, patients with knee metallosis usually present with gradual worsening knee pain and, occasionally, a noticeable rash (indicating necrosis). Prosthetic dislocation is often a late sign and demonstrates significant polyethylene wear^[2]. This almost always goes

on to require revision surgical intervention.

Different companies have different ways in which one can secure the polyethylene liner to the tibial base plate. In the case of the Vanguard® TKR system, one is required to slide the metal clip through both the liner and tibial component, thus allowing for a secure hold of the two. Clip breakage is not a recognised complication of TKR, and very rarely occurs. One would expect that when the clip breaks, this disrupts the position of the polyethylene component, which would ultimately lead to displacement or even dislocation of the knee joint. In our case, though we found the insert to be stable, we concluded that the broken and loose part of metal clip was abrading the metal back components of the joint, and thus triggering the metallosis inflammatory reaction.

When there is a suspicion of post-operative knee metallosis, imaging may help in coming to this diagnosis. Described in the literature are the metal-line sign and the cloud sign which occasionally can be seen on plain radiographs^[2,3].

With regards to the pre-operative radiographic images (Figures 1A and B) it was not immediately recognised that the clip had broken and moved out of position. In retrospect, there is a suspicion that the broken metal clip is visible in the initial set of radiographs. Whether or not pre-operative recognition would have aided in planning is debatable, as the decision to debride the joint was made on clinical grounds of a possible diagnosis of septic

arthritis. Liner exchange could not be carried out at the first instance due to non-availability of the insert and clip as these components were no longer used by the trust - something which, with more detailed pre-operative imaging, potentially could have been planned for and potentially could have allowed her to have a single staged procedure.

CONCLUSION

Metallosis is most commonly caused by wear of the polyethylene insert, leading to a chronic inflammatory process with signs that may or may not be easily identifiable on plain radiographs. Septic arthritis is potentially fatal and thus requires a thorough work up. Once septic arthritis is excluded, early diagnosis of metallosis is key and often requires revision surgery in terms of debridement with or without implant exchange.

We present a rare case of metallosis from what was thought to be a robust mechanism of polyethylene liner stabilisation. We urge all clinicians to bear this in mind when dealing with prostheses which have the potential to allow any form of MOM interaction(s).

REFERENCES

- 1 **Argenson JN**, Parratte S. The unicompartmental knee: design and technical considerations in minimizing wear. *Clin Orthop Relat Res* 2006; **452**: 137-142 [PMID: 16906108 DOI: 10.1097/01.blo.0000229358.19867.60]
- 2 **Romesburg JW**, Wasserman PL, Schoppe CH. Metallosis and Metal-Induced Synovitis Following Total Knee Arthroplasty: Review of Radiographic and CT Findings. *J Radiol Case Rep* 2010; **4**: 7-17 [PMID: 22470753 DOI: 10.3941/jrcr.v4i9.423]
- 3 **Paydar A**, Chew FS, Manner PA. Severe Periprosthetic Metallosis and Polyethylene Liner Failure Complicating Total Hip Replacement: The Cloud Sign. *Radiol Case Rep* 2015; **2**: 115 [PMID: 27303496 DOI: 10.2484/rcr.v2i4.115]

P- Reviewer: Drosos GI, Erkan S **S- Editor:** Ma YJ **L- Editor:** A
E- Editor: Bian YN





Published by **Baishideng Publishing Group Inc**
7901 Stoneridge Drive, Suite 501, Pleasanton, CA 94588, USA
Telephone: +1-925-223-8242
Fax: +1-925-223-8243
E-mail: bpgoffice@wjgnet.com
Help Desk: <https://www.f6publishing.com/helpdesk>
<https://www.wjgnet.com>

